

## GLOBAL POSITIONING SYSTEM RECEIVER

### Field of Invention:

This invention in general relates to navigation technology. Further this invention pertains to global positioning system. More particularly this invention relates to Global Positioning System receiver.

### Back Ground :

Global Positioning System receivers are primarily used for navigation purpose. The system generates by way of outputs, position, speed and other vital navigation information. The receiver needs an antenna and with a hardware unit. Hardware unit comprises of Radio frequency (RF) down converter, Correlator and a Navigation processor. The receiver gets satellite signals from the antenna, down converts in RF down converter and processes the signal in the Correlator. The measurement and correlation values from the Correlator are transmitted to a navigation processor (Digital Signal Processor or any other micro controller) for further processing. Position and other navigation informations are computed in navigation processor and transmitted in a standard format which can be used by the system integrators to develop various applications around these Global Positioning System receivers like Fleet Management System, Traffic telematics.

### BACKGROUND ART

This invention is directed a improved 12 channel and single frequency C/A code Global Positioning System receiver. By virtue of the invention the receiver core is realized around a single programmable fixed-point Digital Signal Processor (DSP) microcomputer. The receiver is based on an unique

Soft-Correlator architecture, which allows the complete Global Positioning System signal processing as well as navigation processing functions to be implemented on a single programmable fixed point DSP. This flexible implementation lends itself naturally for interfacing with any standard RF front end. The receiver has all the advantages associated with a software requirement, such as scalability, upgradeability. The low cost, high performance DSP microcomputer totally eliminates the necessity of a micro controller, usually required by conventional receiver architectures. The solution includes a Programmatic Interface to the Global Positioning System receiver Core, which facilitates the OEMs to embed their own applications on the receiver core along with the Global Positioning System function.

The primary object of invention is to develop a complete Global Positioning System receiver core using a single programmable DSP. Using a single programmable DSP was driven by the need to effectively address demands of the emerging applications in the fields of personal navigation, automatic vehicle location (AVL) and traffic telematics. Every new application conceived in these fields invariably involves the integration of Global Positioning System sensor technology with one or more of the technologies from among cellular telephony, hands free telephony, data modems, speech recognition, speech synthesis, audio/video compression, internet access etc. The Global Positioning System receiver according to the invention has been designed to make seamless integration of multiple technologies feasible without any compromise in performance levels and without the need for customizing silicon.

The conventional Global Positioning System receiver requires the following hardware components for its functioning:

- a. Antenna
- b. RF down converter
- c. Hardware Correlator
- d. Navigation processor

It is to be noted that the main design is built around a hardware correlator.

The conventional correlator is used to acquire and track the satellite signals. The correlator resides in an Application Specific Integrated Circuit, which is a hardware chip that is customised to the needs of the correlator.

The number of gates required in the Application Specific Integrated Circuit depends on the complexity of the correlator. By way of example the gates required for a 12 channel correlator is twice the gates required for a 6 channel correlator.

The conventional Global Positioning System receiver uses a specific Radio frequency down converter for a specific correlator.

The correlator in the conventional Global Positioning System receivers, based on the Application Specific Integrated Circuit has several drawbacks which are listed below :

- ❖ It requires the usage of 4 hardware units. This makes the Global Positioning System receiver a costly device. The device also consumes a lot of power.

- ❖ As the complexity of the correlator increases, the cost of the Application Specific Integrated Circuit also increases. Hence the resultant increase in the cost of the Global Positioning System receiver as well as the power consumption.
- ❖ The performance of the receiver depends mainly on the correlator. Since the correlator resides in an Application Specific Integrated Circuit, which is a customised hardware chip, it is very difficult to implement new signal processing algorithms in the correlator. This feature makes the conventional Global Positioning System receiver inflexible.
- ❖ The correlator is in hardware and if the RF down converter is changed, it is very difficult to change the correlator. This makes the interface of the correlator with 'all' types of RF down converter difficult and contributes to the inflexibility of the system.

### **STATEMENT OF INVENTION**

In the novel Global Positioning System receiver, the correlator is incorporated within the navigation processing unit which resides in a programmable Digital Signal Processor (DSP) chip. The invention thereby eliminates the need of Hardware correlator, and making it easy to implement new signal processing algorithms. Also, the Correlator design can be easily changed in the software to interface with 'any' type of RF down converter. This makes the system very flexible. As there is no hardware Correlator, the cost as well as the power consumption of the Global Positioning System receiver is reduced considerably.

***Salient features of the Invention :***

- ❖ In accordance with the novel Global Positioning System receiver, the programmable DSP processor is incorporated to realise the correlator function and Navigation processor, thereby eliminating the usage of the hardware correlator.
- ❖ In the novel Global Positioning System receiver, a sampling clock is directly connected from DSP to the RF down converter, making it possible to change the sampling frequency in the software to interface with 'any' type of RF down converter.

It is evident that in the novel Global Positioning System receiver, the channel configuration becomes easy. It makes it easy to alter the number of instructions by the programmable Digital Signal Processor.

In order to have complete utilization of the software solution easy, the Global Positioning System receiver according to invention has been designed to include the following novel features:

- (a) flexible software architecture with a programmatic interface
- (b) scalable architecture to translate the advances in the DSP core technology into performance benefits
- (c) optimize power consumption
- (d) dynamic mobilization of computing resources to sustain Global Positioning System sensor performance under adverse signal conditions.

The salient feature of the invention is regarding the incorporation of correlation and navigation functions within the navigation processing unit which resides in a programmable Digital Signal Processor chip. It also directly connects a sampling clock from DSP to the RF down converter, making it possible to change the sampling frequency in the software to interface with 'any' type of Radio Frequency down converter.

It is the primary object of invention to invent a novel Global Positioning System Receiver.

It is another object of invention to invent a novel Global Positioning System Receiver which has been designed to make seamless integration of multiple technologies feasible without any compromise in performance levels and without the need for a customized hardware.

It is yet another object of the invention to invent a novel Global Positioning System Receiver to realise the correlator function and Navigation processor, by which the use of hardware correlator is eliminated.

It is another object of the invention to invent a novel Global Positioning System Receiver wherein navigation processing unit resides in a programmable Digital Signal Processor chip.

It is yet another object of the invention to invent a novel Global Positioning System Receiver wherein a sampling clock is directly connected from DSP to RF down converter, making it possible to change the sampling frequency in the software to interface with 'any' type of RF down converter.

Further objects of the invention will be apparent from the ensuing description.

## **DETAILED DESCRIPTION OF PREFERRED EMBODIMENT OF INVENTION**

Now the invention will be described in detail with reference to the drawings accompanying the description.

Fig. 1 shows the plan view of Global Positioning System Receiver Architecture according to the invention and

Fig. 2 shows the components of Global Positioning System Receiver according to invention.

### **ARCHITECTURE**

The Global Positioning System receiver according the invention is a highly integrated design comprising of two principal blocks (figure 1):

1. RF Down Converter
2. Global Positioning System Signal Processor

Global Positioning System Receiver according the invention use any standard RF down converter. The front end is typically a two/three stage superheterodyne receiver with an image rejecting front end and a fully integrated VCO. For handheld applications with passive antenna configurations, an RF front end with an integrated low noise amplifier (LNA) is preferable, but an external low noise amplifier also can be used if necessary. The down converter derives the sampling frequencies from the

DSP and the resulting quantized signals are fed to the DSP which does all the signal processing and navigation processing.

The DSP also interfaces with low cost non-volatile memory and Real Time Clock to improve the time to first fix in the presence of primary estimates. The Serial communication is established by dedicated serial ports of the DSP, one of which is configured to accept the differential corrections

The Radio frequency down convertor (1) is connected to the Radio Frequency Down converter. A reference Frequency Crystal (2) is connected to the Radio Frequency Down converter. A programmable Digital Signal Processor (3) is connected to Real Time Clock, Radio Frequency down converter, Serial Electrically Erasable Programmable Read only memory. The system has the Real Time Clock (4) and a battery (5) . The Serial Electrically Erasable Programmable Read Only Memory (6) is connected to the programmable Digital Signal Processor. The system has the Byte Electrically Programmable Read only Memory A RS232 driver (7) connected to the programmable Digital Signal Processor and a RS232 driver (8). A correlator (9) interfaces with the hardware. The correlator manager (10) is responsible for giving outputs for Range and Doppler measurements. The Channel Manager (11) controls the correlator manager. The Measurement Data processor (12) is used for short listed satellites. The Satellite data Base manager (13) collects ephemeris and almanac data The Host communication (14) interfaces with Hosts such as PC. The User Computation module (15) gets measurements and outputs the position. The Satellite Position Computation Module (16) computes the satellite position required to compute user position. The Satellite Visibility Computation (17) generates Visible list required by Channel Manager. Non Volatile Memory Manager



(18) interfaces with Non Volatile Memory for storing some important parameters.

### **DSP Microcomputer**

The Global Positioning System Signal Processor is the ADSSTNA V2300, a programmable DSP based on the ADSP218x core, a 16-bit fixed-point microcomputer from Analog Devices which is optimized for digital signal processing and high speed numeric processing. At 75 MIPS sustained performance and a variable voltage operation from a high of 3.3 volts to a low of 2.5 volts, it is ideally suited for high performance, low power GLOBAL POSITIONING SYSTEM signal acquisition, tracking and navigation processing.

The DSP comes in a 100-pin TQFP package and consumes just 1.1875m W/MHz of power internally at 2.5 volts supply voltage, which means delivering 75 powerful DSP MIPS for just 89m W.

It is to be noted that 192 K bytes of on-chip SRAM, which is configured for the Global Positioning System function as a combination of 32K words of 24 bit program memory and 48K words of 16 bit data memory, eliminates the necessity of any external SRAM on the board.

Ample number of interrupts and programmable I/Os available on the DSP take care of the various signaling and time-critical tasks and facilitate the realization of a complete receiver core engine complete with the serial I/Os and time outputs with no external glue logic.

The different low power modes available on the DSP make it easy to implement power saving Global Positioning System algorithms for handheld applications without compromising on the throughput.

The DMA ports of the processor interface with peripherals and exchange data in the background, all happening while the core functions of Global Positioning System run at full speed in the foreground.

The navigation software solution is source code compatible with the future generations of the fixed point family of DSPs from Analog Devices, which means that there is virtually no limit for the possibility of delivering improved Global Positioning System sensor performance at lower cost, size and power.

### **FLEXIBLE SOFTWARE ARCHITECTURE**

One of the salient features of the invention is that the Software Architecture of the Global Positioning System Receiver is designed around a few hardware interrupt service tasks, which attend to time critical events, and timer based periodic and deterministic tasks which are invoked by a Scheduler.

It is to be understood that the receiver software has the following types of tasks :

1. Initialization tasks
2. Interrupt tasks
3. Periodically invoked tasks

Initialization tasks are invoked once on power up/reset. These tasks initialize the receiver hardware and software and perform the built in Self-test and calibration functions.

Interrupt tasks gain control of the DSP asynchronously, anytime after the software is initialized by the Initialization tasks. They are activated by hardware events.

Periodically invoked tasks are invoked at predefined intervals.

The functional decomposition of the navigation system and software is depicted in the figure 2:

The functional components of the software are grouped under two categories:

1. Signal Processing tasks
2. Navigation tasks

#### **Signal Processing tasks**

The signal processing tasks are executed typically in response to high priority, high frequency interrupts and are predominantly intensive users of the DSP instruction set.

#### **PROGRAMMATIC INTERFACE**

The Global Positioning System receiver under the invention has a unique Programmatic Interface using which a system developer can integrate his/her application with the Global Positioning System core library on the same DSP, without having to use another microcontroller.

*The interface enables the application developer to:*

1. Access the necessary Global Positioning System data structures
2. Make use of the real time Global Positioning System outputs
3. Link the application software to the Global Positioning System core engine library
4. Make maximum use of spare computing assets of the DSP

The periodic mode of operation allocates a fixed time slice to the user's application every second. In the background mode all the spare MIPS are made available to the user's application. The choice of the mode for a particular application rests with the application developer.

The developer can write his/her own code either in gun C (ANSI C compatible from Free Software Foundation) or ADSP218x assembly. He/she can access, if necessary, all the real-time Global Positioning System outputs through data structures. The user's object code should be linked with the Global Positioning System core library to generate the executable.

## **POWER CONSUMPTION**

The Global Positioning System receiver under the invention suits the requirements of low power hand held Global Positioning System applications, by virtue of its memory integrated single chip design and the various low power modes of the ADSP218x core.

Under conditions when the receiver continuously tracks all visible satellites and collects data from them, the complete Global Positioning System receiver under the invention reference design consumes about 465m W.

The solution also includes the following options for saving power:

1. User configurable output rates
2. Only-on-demand generation of outputs
3. Channel autoconfiguration

***User configurable output rates***

User can configure the rate at which navigation outputs are desired from the Global Positioning System sensor. The average power consumption of the entire Global Positioning System reference design at different output rates will be as shown in the table below:

Configured Rate	Power Consumption (average)
1 fix per second	130m W
1 fix per 5 second	75m W
1 fix per 10 second	63m W

***Only-on-demand generation of outputs***

The User can configure the receiver to generate navigation outputs only when demanded. In this mode, the receiver will be in a low power state by default and will wake up only upon receiving a request from the host for a

fix. The receiver will be active for just a fraction of a second to compute all navigation outputs and will revert back to the low power mode.

The power consumption will be about 130 mW per fix every second and will decrease with less frequent demands from the host.

### **Channel Autoconfiguration**

Channel autoconfiguration will further reduce power consumption, by including only the barest minimum number of satellites in the navigation solution without compromising on the DOP limits.

*All the calculations of power consumption above assume :*

1. All the devices operate at 2.7 to 3.3 volts
2. There is a built-in LNA on the RF down converter
3. No external LNA used on the board
4. Passive antenna configuration
5. 8 satellites are included in the constellation on an average

### **TTFF (Time to First Fix)**

The TTFF performance of the Global Positioning System receiver under the invention is greatly enhanced by virtue of the powerful DSP instruction set and innovative algorithms. Use of low cost, low ppm crystals do not degrade the TTFF performance. The various TTFF measurements carried out on the Global Positioning System receiver under the invention are as follows:

Time	With at least 4 visible SVs with nominal signal strength	With at least 4 visible SVs with good signal strength
Maximum	78 seconds	54 seconds
Minimum	34 seconds	26 seconds
Average	65 seconds	45 seconds

In the table above, the values assume that the combination of 4 satellites results in a DOP less than that configured by the user. The TTFF figures mentioned above assume a receiver reference clock with a stability of 20 ppm.

## SIZE

The reference design of the Global Positioning System receiver under the invention has a small form factor of 51 x 41 x 12mm. The size can be easily reduced to 41 x 41 x 10mm for passive antenna configurations.

## OEM SUPPORT

The navigation solution is backed by a software and hardware support team, which can cater to the customization needs of OEMs/application developers. For the convenience of the OEMs' production line, the Global Positioning System receiver under the invention solution includes the *OEM Firmware Configuration Kit*, which facilitates the generation of executable navigation software binary files with all the desired EERPOM settings for the configurable parameters such as the DOP limit, almanac, Global Positioning System parameters.

## **EMBEDDED GSM/TRUNKED RADIO INTERFACE**

The receiver firmware comes with an optional embedded GSM interface, conforming to the ETS 07.07 and 07.05 specifications. This enables integration of Global Positioning System receiver under the invention with GSM mobile stations.

Also, the Global Positioning System receiver under the invention includes as optional proprietary binary message protocol to interface the Global Positioning System sensor with a modem, to facilitate connection to a VHF/UHF transceiver.

## **DR INTERFACE CAPABILITY**

The OEM can implement a hybrid navigation system by including hybrid navigation algorithms on the Global Positioning System core DSP itself, making use of the Programmatic Interface.

Details description of the modules involved:

The receiver gets the RF signal through an antenna and the signal is passed through at 'RF down converter'. RF down converter down converts the 1575.42MHz signal to an intermediate IF. The down converter is a triple stage converter with filters to cutoff image frequencies. The IF signal in the RF down converter is converted to digital signal using A/D converter in the converter.

The digitized IF is taken by the programmable DSP to do baseband processing. The base band processing involves 'correlation' of 12 channels, code and carrier tracking, data demodulation and measurement generation.



The measurements and demodulated data of each channels are processed to find the user position. As the processing is done in a programmable DSP, the number of channels can be increased based on the availability of MIPS and Memory.

The DSP is interfaced to a boot eprom where the code resides. The DSP boots the code into its internal memory during power on.

The RF down converter is interfaced to a good stability crystal which is used as a reference to generate all the local oscillator clocks in the RF down converter. The stability of this crystal some times determines the performance of the receiver. As the programmable DSP is used a low cost crystal can be used with minimum impact on the performance of the Global Positioning System receiver.

A real time clock is provided to keep track of the time to speedup the acquisition time during certain condition. An EEPROM is also provided for the same purpose. The almanac, ephemeris information along with the approximate time and position is used to speed up the acquisition time. Now the invention addresses the utility of the system to various applications

***Various tasks include the following:***

1. Correlator which acquires and tracks signals from up to 12 satellites simultaneously, given the Correlation values as output every millisecond

2. Correlator Manager which controls and monitors the channel of the Correlator, carries out Range and Doppler measurements and extracts navigation message
3. Satellite Database Manager which maintains the database of navigation messages in the receiver
4. Channel Manager which assigns appropriate satellites to all the channels of the Correlator for acquisition
5. Measurement Data Processor which filters the Pseudorange and Doppler measurements for all tracking satellites and validates the measurement data for use in the navigation solution.

#### **Navigation tasks**

These tasks are executed in response to less frequent but periodic events and some of these are floating point computation intensive. These include:

1. User Position Estimation Module which estimates the accurate position, velocity and time
2. Satellite Visibility Computation and Satellite Selection Module which computes the list of visible satellites based on the estimates available
3. Satellite Position Computation Module which computes the precise position and velocity of the satellites for use in the navigation solution
4. Host Communications Module which communicates with the host through RS232 link
5. Non Volatile Memory Module which manages the data in the EEPROM and RTC

The powerful floating-point library available on the DSP core enables very efficient execution of the floating-point intensive tasks. However, the architecture of the Global Positioning System receiver under the invention makes it feasible for the OEMs to migrate the Navigation tasks to a separate microcontroller while still maintaining a seamless interface with the signal processing tasks residing on the ADSSTNAV2300, if their overall system design considerations necessitate such a partitioning.

The invention can find its application in car telematics unit, orbit determination of satellites, fleet management applications etc. But the main advantage of the invention lies in its programmability.

For example consider a car telematics unit. The vital components for such a car telematics unit consists of Global Positioning System receiver, GSM phone, Audio synthesis, voice recognition system etc. The system integration of these components involves enormous cost and time. If each of these components are available as software modules which can be run on a single processor, the hardware cost and complexity can be reduced drastically. The programmatic Global Positioning System such as the invention help in this direction.

As the invention runs on a processor without any base band hardware, any new enhancements to the signal processing chain can be easily incorporated.

Therefore customization of the product is much easier when the system namely Global Positioning Receiver is used.

It is to be noted that the object of the description is to explain salient features of the invention. It is to be further noted that the description is in no way restrict the scope and ambit of the invention. It is evident that within the scope of the invention various amendments and modifications are permissible. The scope of the invention is defined in the following statement of claims.

## CLAIMS

1. A novel Global Positioning System Receiver intended to perform both the correlation and navigation functions, facilitating easy channel configuration to change the sampling frequency in a software to interface with 'any' type of radio frequency down converter, comprising a RF down converter and GPS signal processor characterized in that, correlator is incorporated within the navigation processing unit which resides in a programmable digital signal Processor chip to realise the correlator function and navigation processor to eliminate the use of hardware correlator, a sampling clock being directly connects. the DSP to the RF down converter making it possible to change the sampling frequency in the software to interface with any type of RF down converter.
2. A novel Global Positioning System Receiver as claimed in claim 1 wherein the correlator resides in an application specific integrated circuit.
3. A novel Global Positioning System Receiver as claimed in claim 1 wherein application specific integrated circuit is a hardware chip which is customised to needs of the correlator .
4. A novel Global Positioning System Receiver as claimed in claim 1 wherein the GPS receiver has been designed and modules incorporated to make seamless integration of multiple technologies feasible without any compromise in performance levels and without the need for a customised hardware.

5. A novel Global Positioning System Receiver as illustrated in the accompanying drawings and as substantially herein described.

## **ABSTRACT**

Global Positioning System Receiver is primarily used for navigation purpose. This novel receiver is intended to perform both the correlation and navigation function thereby facilitate easy channel configuration. The device facilitate to change the sampling frequency in the software to interface with any type of Radio Frequency down converter. The correlator is incorporated within the navigation processing unit which resides in a programmable Digital Signal Processor chip. A sampling clock directly connects the DSP to the RF down convertor.

1/2

Fig 1

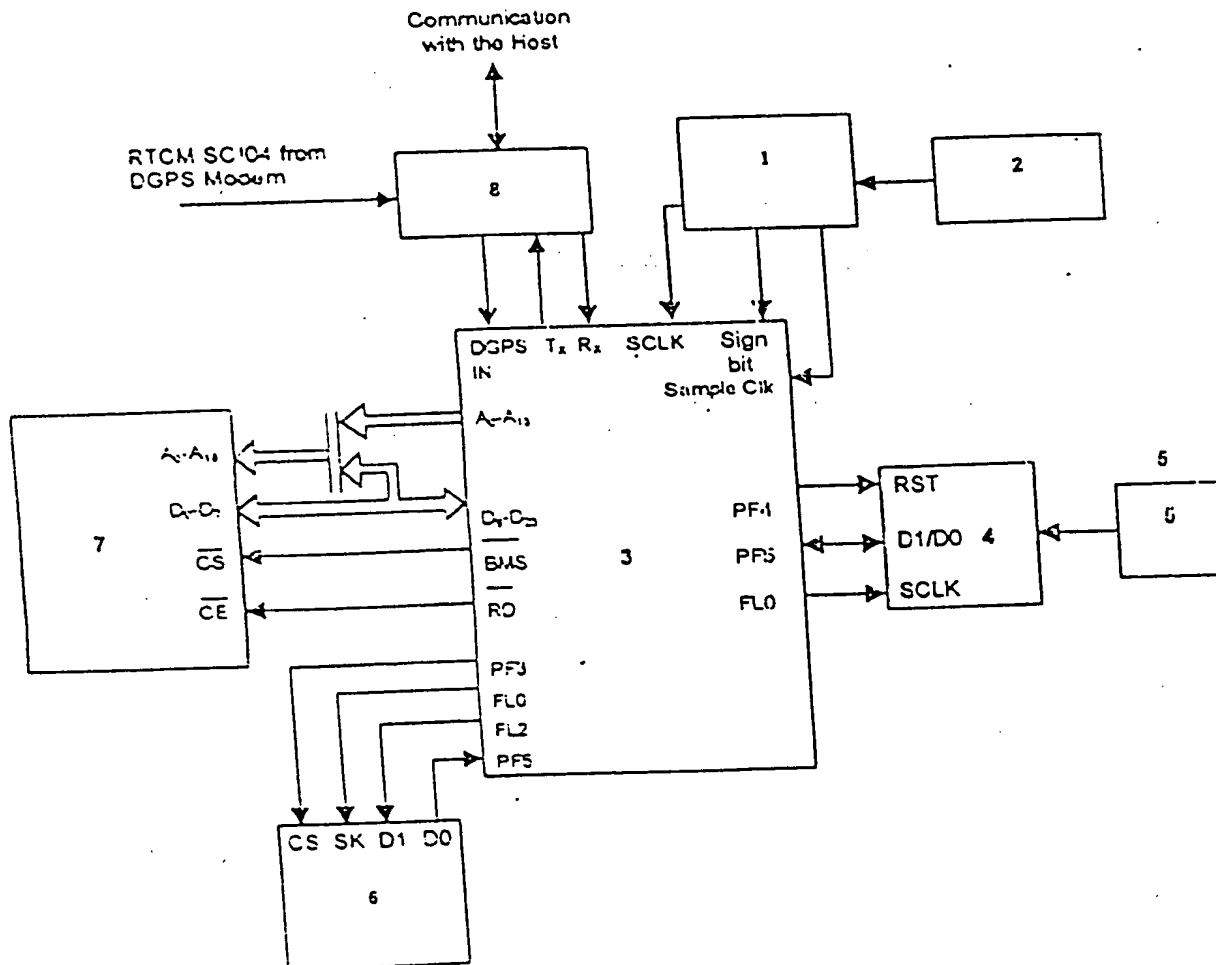
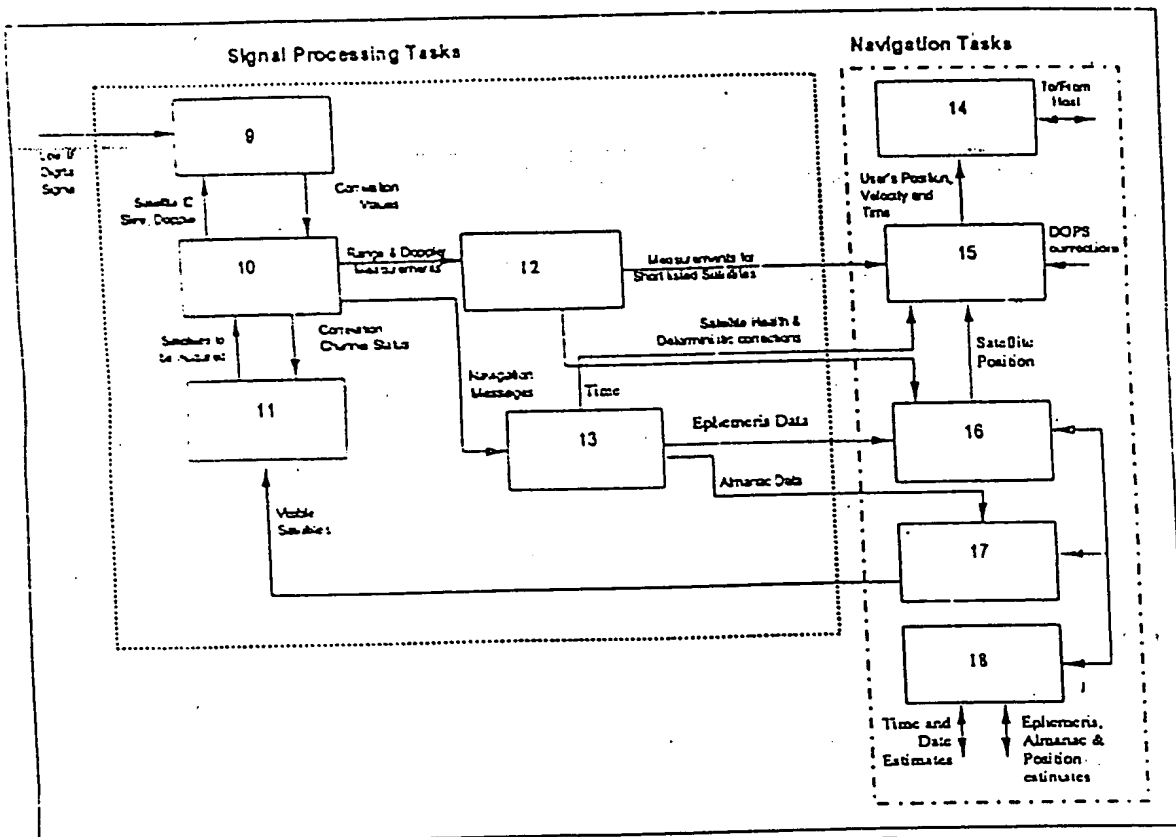




Fig 2



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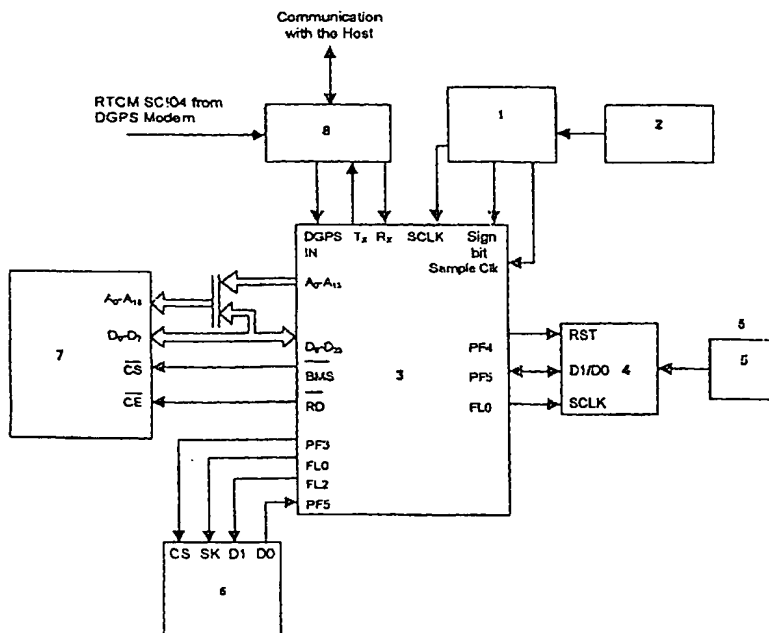
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) GPS, SAMPLING, CLOCK, CORRELATOR												
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>												
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.										
X	US 5,689,271 A (LENNEN) 18 November 1997 (18.11.97) Figs. 1 and 2	1-5										
X	US 6,091,785 A (LENNEN) 18 July 2000 (18.07.00) Figs. 1, 6 and 11	1-5										
A	US 6,259,401 A (WOO) 10 July 2001 (10.07.01)	1-5										
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